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MICROWAVE TRANSMISSION NODE OPTIMIZATION FOR ACCESS CAPACITY INCREASE IN MOBILE NETWORKS

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Abstract

Mature mobile networks heavily utilize the available access transmission (TRS) network (NW) capacities. Any new capacity demand may unavoidably lead to optimization. Modernization projects inherently offer the possibility of optimizing dense microwave (MW) access networks.

1. Introduction

Density of MW links has been increased rapidly in the last decade [1-5], mainly due to the quick expansion of mobile networks. In GSM the main task of the access TRS network is to provide the A-bis interface to connect sites to BSCs (Fig.1). A typical GSM/UMTS access NW is composed of SDH and PDH sections. The physical media are MW radio links, optical fiber (SDH sections or leased line (LL)) or copper cable (typical for LL) connections. Hundreds of 2G/3G base stations (BTS) are connected to BSCs/RNCs over MW radio links thanks to the advantage of rapid implementation and relatively moderate monthly fees (e.g. compared to optical fiber implementation or monthly LL costs).

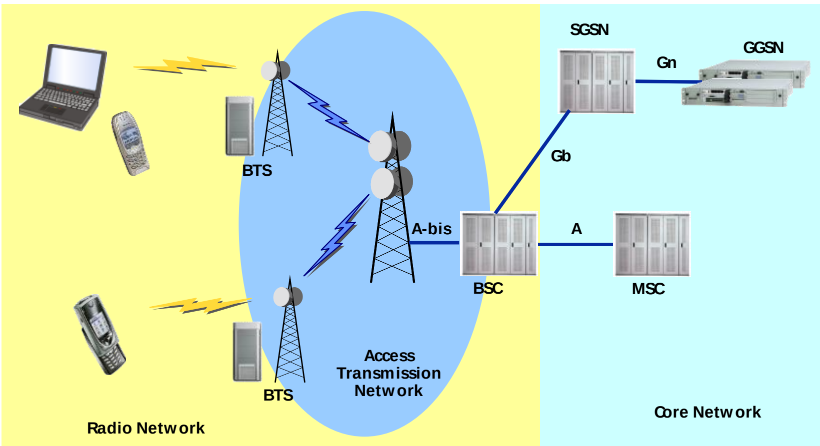

Fig.1. Architecture of mobile network showing the radio access transmission network

As digital microwave radio (DMR) technology developed simultaneously with the strongly increasing demand, state-of-the-art DMRs offer numerous advantages compared to older DMR versions. Possibility of remote control (e.g. setting the output power or transmit frequency, electrical cross-connection of transmitted digital signals), error correction techniques, automatic transmit power control (ATPC), built-in bit-error (BER) testing possibility make the network operation and maintenance easier, more reliable, flexible and cost effective.

2. Modernization of Digital Microwave Radio Links

A mobile operator in Switzerland significantly improved its access transmission network by modernization. Nearly 500 MW radio links have been replaced and capacity upgraded during the modernization project (Fig.2 and Fig.3). Old DynaHopper radios were replaced by new FlexiHopper Plus [6] or MetroHopper radios. Significant OPEX savings were realized with simultaneous capacity increase in the overall TRS network.

Nokia Radio Type	FlexiHopperPlus		FlexiHopper		DynaHopper		
Capacity	8x2	16x2	8x2	16x2	8x2	16x2	Mbit/s
Bandwidth	7	14	14	28	14	28	MHz
Pout (nominal TX power)	18	18	18	18	17	17	dBm
VHP2-220A (60 cm) antenna					40.1	40.1	dBi
VHLP2-220 (60 cm) antenna			40.1	40.1			dBi
VHLP2-23 (60 cm) antenna	40.4	40.4					dBi
BER=10-3 threshold, guaranteed	-82	-79	-86	-83	-79	-76	dBm
BER=10-6 threshold, guaranteed	-79	-76	-83	-80	-75	-72	dBm
System Gain, (BER=10-3)	100	97	104	101	96	93	dB
System Gain, (BER=10-6)	97	94	101	98	92	89	dB
System & 2xAnt.Gain, (BER=10-3)	180.8	177.8	184.2	181.2	176.2	173.2	dB
System & 2xAnt.Gain, (BER=10-6)	177.8	174.8	181.2	178.2	172.2	169.2	dB
Gain increase compared to DH	4.6	4.6	8	8	0	0	dB
Gain increase compared to DH	5.6	5.6	9	9	0	0	dB

Tab.1. Comparison of FlexiHopper Plus, FlexiHopper and DynaHopper radios

The main task of the modernization project was to provide the extra TRS capacity required for EDGE deployment. Then remaining free capacities helped the operator in UMTS and HSDPA deployment. In practice most of the 2G and

3G sites are co-located so usually the same TRS NW is shared. During the design of the MW link swaps, the latest regulations of the local Communication Authority were kept. Comparison of the main technical parameters of the different Nokia radios is given in Tab.1.

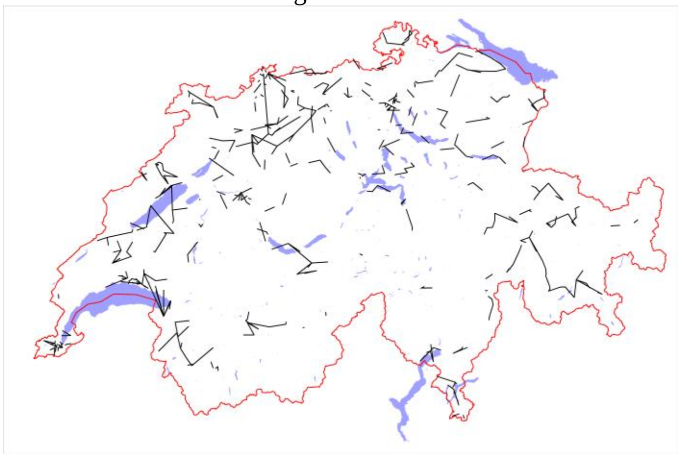

Fig.2. 460 MW links swapped and capacity upgraded in Switzerland

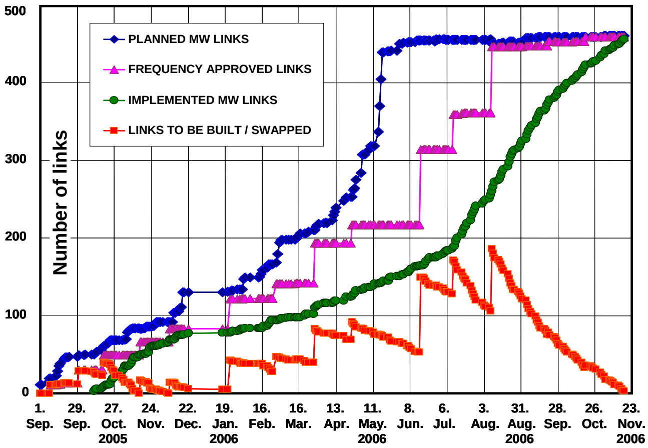

Fig.3. Number of MW links planned, frequency licensed and implemented

2. Basic Rules of Microwave Transmission Node Design

There are some basic rules listed in Tab.2 that must be followed in order to achieve high spectral efficiency and better frequency re-use in radio access networks. Even though these rules are well-known they cannot be always followed, as real-life networks develop "evolutionary". Mobile networks undergo continuous deployment and changes. New and newer sites are coming up and sometimes old sites are demolished. To provide the connection of the new sites new links must be added to the already existing MW network. Each new link requires interference calculation and the proper frequency is selected if possible [4]. However, at a certain point of complexity the developed network show interference when new links are added and we cannot enter any new link without modifying some of the already existing links [5].

Rule 1:	Always select the proper frequency band. Long links should use the lower frequency bands (e.g. 13 or 15 GHz), short links should use as high frequencies as possible (23, 38 or 58 GHz). In several countries there are local regulations forcing all the network operators for efficient band selection. The Swiss regulation is shown in Fig.4, as an example. [7-10]
Rule 2:	Avoid High-Low (H/L) conflict on sites to eliminate the near-field interference. Frequency Division Duplex (FDD) radios have high transmit/low receive and low transmit/high receive frequency sub-band variants. As a general rule, it is recommended to use always the same sub-band of the radio links on a given site. In some cases the near-filed interference may be shadowed by obstacles, e.g. concrete walls on building rooftops and the H/L conflict rule can be disregarded. Naturally, the rule is not relevant for Time Division Duplex (TDD) radios that transmit and receive in the same frequency. Finally, it is obvious that a site can be "Low" in 23 GHz but "High" in 38 GHz band. Fig.5. shows the case of H/L conflict.
Rule 3:	Try to use minimum output power. As shown in Fig.6, low output power helps to avoid overshooting interference. Instead of high output power and small antenna, preferably low output power and bigger dish size is recommended. This configuration better supports capacity upgrade on the link if required later.
Rule 4:	Preferably use high gain and high performance antennae [11]. High antenna gain can compensate the low output power, recommended in rule 3. High performance antennae reduce the transmission of power density into unwanted directions (Fig.7). Some Authorities combine rule 1, 3 and 4 in a distance dependent maximization of EIRP (Equivalent Isotropically Radiated Power).
Rule 5:	Use proper polarization to increase discrimination between neighboring links [5]. In practice, at MW node points it means a systematic order of swapping link polarizations between Horizontal (H) and Vertical (V): e.g. H, V, H, V, H, V…. In that way neighboring links, which have smaller angular discrimination benefit from significant polarization discrimination (approx. 30 dB).
Rule 6:	Balance Received Signal Levels (RSL) at nodal points terminating several MW links. Decreasing the difference between RSL of different links reduce the probability of harmful interference. In some countries, e.g. Switzerland the Authority defines the range of RSL to fall into -43 dBm…-40 dBm.
Rule 7:	Calculate interference with proper MW link design tools. Use proper set of interference matrices from real radio measurements. Even powerful network planning tools can derive bad conclusions if interference matrix is not correctly entered or not entered at all (default values are used) [12].
Rule 8:	After planning and implementing the new link, monitor the most important parameters of the link via OSS for a while (e.g. frequency, TX power, RSL, BER of the link) to detect mistakes in planning or implementation.

Tab.2. Basic rules in dense MW access NW design

Distance(km)	0.15	1	3	5	6	7.5	10	12	15
52 or 58 GHz	Vertical								
38 GHz		Horizontal	Vertical						
23 GHz				Horizontal		Vertical			
13 GHz							Horizontal		Vertical

Fig.4. Polarization and Distance Rule

When a new link cannot be simply inserted into the existing access network and topology, optimization takes place. Dense access networks often require optimization. In the lucky case the required modification is only frequency change on some previous links that can be done by remote control. State-of-the-art MW transmitters (e.g. Nokia FlexiHopper, FlexiHopper Plus or MetroHopper radio family) support frequency change by remote control via OSS. In unlucky cases either polarization or antenna size of the link must be changed or maybe selection of a different frequency band is needed. Any of these require extra work on the field. In such a case a complete revision of the area may provide longer term solution. This is especially true if available free capacities are not sufficient and some of the links must be capacity upgraded anyway. In other words, a regional optimization can be combined with modernization of old links.

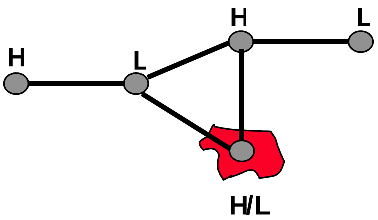

Fig.5. High/Low conflict on site

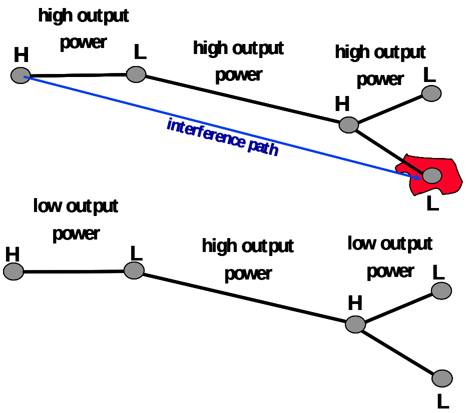

Fig.6. Usage of proper output power

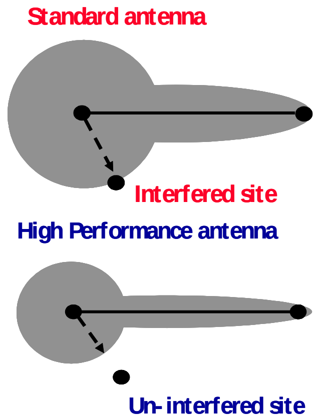

Fig.7. High performance antenna

3. Example of Microwave Node Point Optimization

MW node points that are often called as "repeaters" or "high transmission points" are frequently used to collect the mobile traffic of several base stations. Following the rules mentioned in the previous part, a complete MW node point was optimized. The result is presented here as an example: Tab.3 lists ten MW links that were re-designed to avoid interference. Due to morphological constraints the links close a narrow angle. The topology is shown in Fig.8. Due to the morphological difficulty (hills and lake) more and more sites were connected to the repeater (VS803). In the past years unfortunately all the links were built and licensed with the same vertical polarity. Except one hop (Link 10) all links used the same 23 GHz band. This resulted in interference as predicted by the link planning tool [12].

	Site name / Site ID	Ollon VD431 – Chavalon VS803	Chavalon VS803 – VD954 VD954	Territet VD422 – Chavalon VS803	Gion VD454 – Chavalon VS803	La Chiesaz VD406 – Chavalon VS803	Sully VD417 – Chavalon VS803	Legier VD411 – Chavalon VS803	Corseaux VD881 – Chavalon VS803	Pelerin VD804 – Chavalon VS803	Mollie Margo VD801 – Chavalon VS803
	Link number	Link 1	Link 2	Link 3	Link 4	Link 5	Link 6	Link 7	Link 8	Link 9	Link 10
	hop length [km]	11.03	9.4	9.11	11.33	14.49	11.29	13.25	14.7	17.25	26.08
NEW	interference	no	no	no	no	no	no	no	no	no	no
NEW	new capacity	4x2	8x2	4x2	4x2	8x2	4x2	8x2	16x2	32x2	16x2
NEW	new channel [MHz]	59 22417.5 23425.5	54 22382.5 23390.5	57 22403.5 23411.5	61 22431.5 23439.5	64 22452.5 23460.5	56 22396.5 23404.5	53 22375.5 23383.5	30 22421 23429	H:12 12912/13178 V:13 12926/13192	11 12898 13164
NEW	new polarization	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	X-polar	Vertical
NEW	new fr. band	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	13 GHz	13 GHz
NEW	new radio	FH	FHP	FH	FH	FHP	FH	FHP	FHP	FHP X-polar	FHP
OLD	old radio	FH	DH	FH	FH	DH	FH	FHP	FH	FH	FH
OLD	old fr. band	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	23 GHz	13
OLD	old polarization	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical
OLD	old channel [MHz]	53 22375.5 23383.5	52 22368.5 23376.5	57 22403.5 23411.5	65 22459.5 23467.5	49 22347.5 23355.5	59 22417.5 23425.5	66 22466.5 23474.5	14 22386 23394	16 22442 23450	6 12905 13171
OLD	old capacity	4x2	4x2	4x2	4x2	4x2	4x2	8x2	16x2	16x2	16x2
OLD	Interference	yes	no	no	yes	yes	yes	yes	yes	yes	no

Tab.3. Example of MW node point optimization for access transmission capacity increase

As seen in the "NEW" part of Tab.3 the latest distance, polarization (Fig.4), RSL and spectral efficiency rules of the Swiss Authority are all kept. As a first step, two old DynaHopper radios were swapped to Nokia FlexiHopper Plus radios. As a consequence the access capacity of Link 2 and Link 5 was doubled. As a second step the channels of the individual MW links were shifted into the frequency sub-band dedicated for the operator. This frequency shift had a historical background. Namely, the local Authority changed the preferred channels during the past six years to achieve easier management and better spectrum efficiency nationwide. Shaded channels in "OLD" part of Tab.3 are not allowed any more. In the new design, rule 5 was kept and proper isolation between the links was achieved by polarization alternation (V, H, V, H…). Furthermore the longest 23 GHz link (Link 9) was shifted down to the 13 GHz band. In that way the reliability of the link was increased (rain attenuation). Furthermore the new 13 GHz link was designed as a dual-polar link doubling the capacity from 16x2 to 32x2 Mbit/s. Finally, as seen in Tab.3, the total access TRS capacity increased from 80x2 up to 104x2 Mbit/s meanwhile possible interference between the links were significantly reduced.

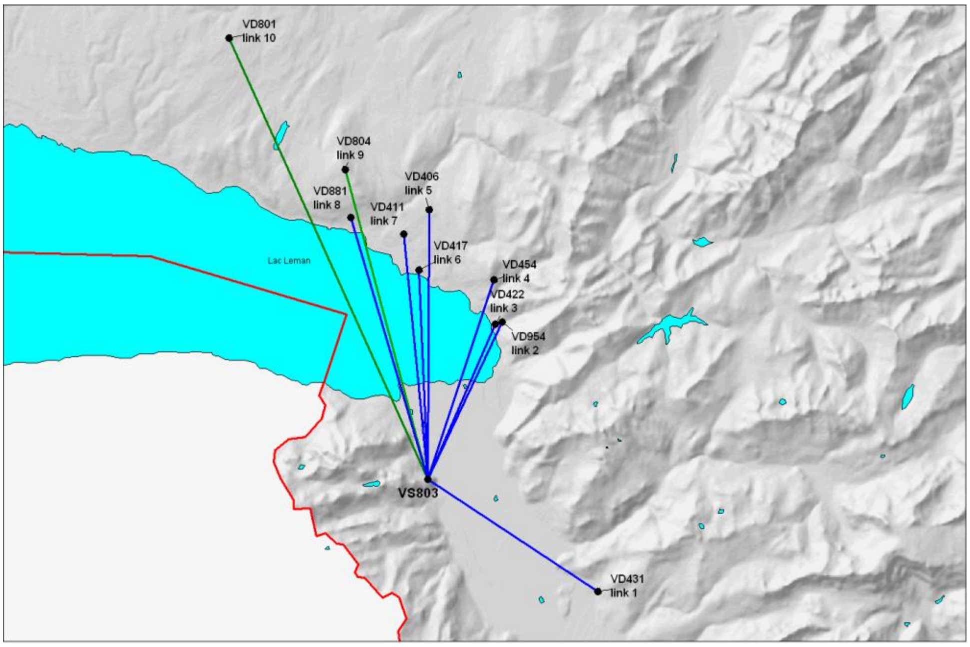

Fig.8. The topology of repeater "VS803" optimized for access capacity increase

4. Conclusions

Actual GSM networks are typically 10 years old in Europe. Modernization of old network elements results in better system performance, more flexible operation and reduced cost of maintenance. In the presented example the mobile network modernization targeted the access transmission network part. Nearly 500 MW radio links were swapped for new state-of-the-art Nokia MW radio links and upgraded providing capacity increase in the same occupied RF bandwidth. Furthermore, optimization helped to remove some interference problems inherited from the past. As an example, a TRS node point optimization was presented and the most important planning rules were discussed.

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